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CHANGES IN THE TREE AND DWARF SHRUB FINE-ROOTS AFTER CLEAR-CUTTING IN A MATURE SCOTS PINE STAND*

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*Nomenclature follows Lid (1974) for vascular plants

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Abstract

The changes in the tree and dwarf shrub fine-roots were investigated in a mature Scots pine (*Pinus sylvestris*) stand Ih 0 at Ivantjärnsheden in Central Sweden before and up until five years after clear-cutting. Sampling was made in two strata, which, in the clear-felled phase, were designed as areas with (I) and without (II) twice the ordinary amount of felling litter. Two methods were adopted for the root investigations: (1) core sampling on sequential sampling occasions, (2) sampling of soil blocks (monoliths) divided into vertical 10 cm sections.

The root systems of *P. sylvestris*, *Calluna vulgaris* and *Vaccinium vitis-idaea* survived for a period of two growth periods after clear-cutting with partly living root fractions (biomass). There was a gradual decrease in the fine-root biomass (< 2 mm in diameter) for both *P. sylvestris* and *C. vulgaris* during the first two years after clear-cutting, followed by a temporary increase in the fine-root necromass when all the roots died. However, as regards fine-root biomass plus necromass of both species, there was a decrease during the whole period of study. No coincident change was observed in *V. vitis-idaea*. There were not found any decisive differences between the two strata. Data from soil block samplings carried out in Ih 0 and the nearby located Ih V revealed no remarkable differences in the spatial distribution of root systems.

Additional keywords: *Calluna vulgaris*, decomposition, fine-root biomass, fine-root necromass, *Pinus silvestris*, soil cores, *Vaccinium vitis-idaea*.

Introduction

Plant roots are the connecting link between the plant and the soil. In many ways, roots have remained the least explored structural unit of plants. For many reasons, it is essential to improve our understanding of the below-ground processes from the time when the plant organs are still living to the point at which they become organic matter again.

The main aim of the present study, which was carried out within the Swedish Coniferous Forest Project (SWECON), was to measure the changes in the fine-root population in a Scots pine (*Pinus sylvestris*) stand subjected to clear-cutting, in order to shed light on how the root biomass components change over a sequence of years. The method adopted for the study of the temporal variations in the fine roots was to use data obtained by sequential core sampling over a number of years. The root fragments were separated into living (biomass) and dead (necromass) fractions, which were subsequently confirmed and weighed.

The studies within SWECON demonstrated the important role of fine roots in the carbon cycle of coniferous forest ecosystems (cf. Ågren et al., 1980; Ericsson & Persson, 1980; Persson, 1981). The carbohydrate supply does not normally limit root growth; most forest trees generally seem to invest a substanital amount of energy in fine root growth (and in mycorrhiza) from a relative carbohydrate surplus. The fine roots, especially, exert a significant influence on the soil profile development and, when dead, contribute considerably to the organic matter of the soil (cf. Persson, 1978; 1979; 1980a; 1980b; 1980c; 1981).

Material and methods

The investigation was conducted in an approximately 120-year-old Scots pine (*Pinus sylvestris*) stand, which was clear-felled during the winter of 1976. The stand (Ih 0) was located at Ivantjärnsheden, Jädraås in Central Sweden (lat. 60°49'N, Long. 16°30'E, Alt. 185 m above sea level). The forest type is of lichen to lichen-dwarf-shrub type (cf. Ebeling, 1978). This fairly thin Scots pine stand, with suppressed dwarf individuals of Norway spruce (*Picea abies*) underneath, originated in the 1850s (cf. site description in Axelsson & Bråkenhielm, 1980).

The tree stand was thinned by the removal of weak trees in 1962. The previous history of Ih 0 tallies mainly with that of the nearby Ih V, which can thus be used as a control (cf. Table 2 and 3 in the text). The tree layer in Ih 0 was, however, somewhat denser. A description of the vegetation at Ivantjärnsheden is found in Bråkenhielm & Persson (1980). The mean annual precipitation in the Jädraås region (1931-60) is 607 mm. However, considerable variations occur from 413 to 776 mm. The mean annual temperature (1931-60) is +3.8°C (cf. Axelsson & Bråkenhielm, 1980).

Ih 0 as a whole covers 85 x 225 m, divided in its central parts into 12 quadrats of 20 m^2 for intensive field sampling. Six of these 20 m^2 quadrats were cleared of felling litter (e.g. slash from branches and needles) in connection with the clear-felling in March-April 1976. The felling litter was evenly distributed on the remaining six quadrats. In this way two strata were established in the clear-felled phase, e.g. areas with (I) or without (II) twice the ordinary amount of felling litter.

The number of core samples on each sampling occasion was 18, in each one of the two strata I and II. The soil cores were removed with a long steel corer, which had an internal diameter at the hardened steel cutting edge of 6.7 cm (area 35.26 cm^2). The core sampling started in 1975 before the clear-felling of the stand and continued on two occasions during the growth period 1976-1977 and on one single occasion in 1978, 1979 and 1980 (cf. Table 1). The place of coring was selected randomly in special sampling areas within the 20 m^2 quadrats. No samples were taken closer to tree centres than 50 cm.

Additional root sampling was also carried out at the beginning of June 1976, shortly after the clear-felling, using soil blocks (monoliths) (cf. Table 2). All roots within a frame of 50 x 50 cm were then excavated, starting with the F/H layer and continuing with 10 cm sections of the mineral soil down to a depth of 60 cm. The mineral soil sections were sifted in the field in order to reduce the sample volume. All soil samples (both cores and material from the soil block samplings) were stored in a deep-freezer until the final root sorting could take place.

Living and dead root fragments (biomass and necromass respectively) were sorted into different species. This was easily done in the case of *Pinus sylvestris*, *Calluna vulgaris* and *Vaccinium vitis-idaea*, which were most important in terms of weight, since these species have root systems with distinctive morphological features (cf. e.g. Kivenheimo, 1947; Metsävainio, 1931). Other species, e.g. *Betula* spp., *Picea abies*, *Empetrum nigrum* and *Vaccinium myrtillus*, although, occurring only sporadically, in insignificant amounts, were treated separately (they are, however, not dealt with in the present paper). The root fragments were classified into the following diameter fractions: 0-2 mm, 2-5 mm, 5-10 mm and > 10 mm. For the purpose of the present paper, the 2-5 mm and 5-10 mm root fractions were grouped together into a 2-10 mm root fraction. The diameter classes were based on the thickness of the roots or rhizomes at the middle of each fragments measured with callipers. Thus the sorting of the excavated root material was considerably simplified as compared with earlier procedures within SWECON (cf. Persson, 1978; 1979; 1980a; 1980b; 1980c; 1981).

Separation into living and dead roots was based on the degree of cohesion between cortex and periderm. The roots were then cut lengthwise with a sharp dissection knife and the section surface was examined under a stereo microscope. This technique was applied only in cases where it was difficult to carry out a direct visual assessment of whether a root fragment was living or dead. Living rootlets are far more resilent than dead ones and do not break so easily if twisted or bent. Dead rootlets are, furthermore, often wrinkled and dark in colour, fine ramifications are shed, and if resistant, are often broken off during sorting.

Results

One immediate observation in the data obtained by the sequential core sampling in Ih 0 (cf. Table 1), is the fact that the different root systems perserved in the form of biomass (e.g. living root tissue) for a surprisingly long period after clear-cutting. However, there was a gradual decrease in the fine-root biomass FRB (< 2 mm in diameter) during the first years following the clear-cutting. Thus, between October 1975 and September 1977 the FRB of *Pinus sylvestris* decreased by 59 % and 61 % in strata I and II, respectively. The related decreases in the FRB of *Calluna vulgaris* were 32 % and 24 %.

At the same time, there was a parallel decrease in the fine-root necromass, FRN, which in the case of *P. sylvestris* was 43 % and 14 % and, in the case of *C. vulgaris*, 44 % and 61 % in strata I and II. With regard to *Vaccinium vitis-idaea*, no coincident decrease in either the FRB or the FRN was observed, the amounts varying extremely during the entire period of study. For all species, the initial root biomass had turned into necromass after 1977. No decisive differences were obtained between the two strata.

It is, furthermore, evident from the data in Table 1, with regard to the coarse-diameter root classes, CRB and CRN, (2-10 mm in diameter) of *P. sylvestris* and *C. vulgaris*, that the irregular occurrence of these fractions in the sample cores had masked the expected temporal changes. Coarse-diameter tree roots are more frequently found near the tree stems and a gradual decrease is observed towards the periphery (Persson, 1980). In the present study, no samples were taken closer than 50 cm to the centres of the tree stems; however, irregular occurrences of coarse tree roots in the samples could not be avoided. With regard to the 2-10 mm fraction of *C. vulgaris*, which consists to a great extent of old stem parts from above ground sections embedded in the F/H layer, one may conclude that decomposition took place rather slowly, since there was no sign of a decline in the present data (Table 1).

A comparison between the mature stands Ih 0 and Ih V (both stands have a similar previous history and are situated in the same region at Ivantjärnsheden; cf. Axelsson & Bråkenhielm, 1980) with regard to the vertical distribution of the different species, reveals no remarkable differences in the distributional pattern (cf. Table 2). Note, however, that the two sets of data are not strictly comparable due to different times of sampling and, in the case of Ih 0, to the fact that the stand had been clear-felled shortly before the sampling was carried out. Data in Table 2 make it clear that only a small portion of the total amount of *P. sylvestris* roots (13 % of FRB+FRN, 12 % of CRB+CRN) was not included in Ih 0 by core sampling, which was carried out to a depth of only 30 cm below the F/H layer. The same may be concluded with regard to the related data from Ih V (only 1 % was not concluded for FRB+FRN and CRB+CRN, respectively).

As for *C. vulgaris* and *V. vitis-idaea* almost no roots at all were found in the deeper 30-60 cm soil sections of Ih 0 and Ih V (Table 2). Whereas the dwarf shrubs were fairly superficially distributed with the major part of their root weight in the F/H layer, the roots of *P. sylvestris* were concentrated to the upper mineral soil horizons. Percentages of the FRB+FRN of *P. sylvestris* in the F/H, 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60 soil sections of 36, 27, 17, 8, 9, 3 and 1 were arrived at in Ih 0 and 49, 41, 8, 1, 0, 0 and 0 in Ih V. The corresponding percentages for *C. vulgaris* were 80, 16, 2, 1, 0, 0 and 0 in Ih 0 and 79, 20, 1, 0, 0, 0 and 0 in Ih V. Even more superficially distributed was *V. vitis-idaea* in Ih 0 with percentages of 93, 7, 1, 1, 0, 0 and 0. In Ih V, however, the corresponding figures were 62, 37, 0, 0, 0, 0 and 0, indicating a somewhat deeper distribution. Also, the figures given above for *P. sylvestris* suggest a deeper distribution in Ih V of the FRB+FRN. The vertical distribution of the FRB+FRN of *P. sylvestris* and *C. vulgaris* in both stands did not differ very much from the distributional pattern of the CRB+CRN.

The bulk of the FRB (< 2 mm in diameter) of *P. sylvestris* consists of fairly thin root ramifications. No data have been obtained in Ih 0 of a < 1 mm diameter-class. However, in Table 3 are to be found corresponding estimates for the nearby Ih II and Ih V stands at the Ivantjärnsheden research site. These figures are pooled averages from extensive samplings carried out in 1974-75 (Persson, 1978; 1979; 1980a; 1980b; 1980c; 1981). It is evident from these data that the major portion, both in terms of weight (around 60 %) and in particular in terms of length (around 90 %) of the < 2 mm diameter-class consists of root ramifications < 1 mm in diameter.

The fine roots < 1 mm in diameter are extremely variable (Persson, 1979; 1980a). Initially, at the sampling in October 1975, the FRB constituted 46 % and 41 % of the total 0-10 mm root biomass of *P. sylvestris* in strata I and II. In June 1977, the related figures were only 16 % and 19 %. The latter decrease in the FRB must be interpreted as a result of a decline in the amount of fine roots in the < 1 mm diameter-class.

Discussion

Very little is known about the changes that occur in fine-root systems after clear-felling; at present, appropriate information is almost entirely lacking in literature. Available works on the temporal pattern of fine-root growth in conifer stands that have not yet been clear-cut indicate considerable variations in the amounts of fine roots during the growing season (cf. e.g. Heikurainen, 1955; Kalela, 1955; Göttsche, 1972; Kohman, 1972; Roberts, 1976; Ford & Deans, 1977; Deans, 1979). As demonstrated in several works by the present author, the fine roots are in a state of constant flux, with death and replacement taking place simultaneously (cf. Persson, 1978; 1979; 1980a; 1980b; 1980c; 1981).

A substantial amount of fine-root biomass is, furthermore, constantly being transformed into necromass (dead fine-root tissue) which is usually not estimated or taken into account in turnover calculations (cf. Santantonio, 1979). The fluctuations in the fine-root necromass may be large during the growing season (cf. Persson, op. cit; Santantonio, 1979).

Although, there is a growing body of evidence (see literature above) that considerable changes take place in below-ground organs, there are comparatively few estimates of the rate of turnover of the fine roots. Noteworthy exceptions are: Harris *et al*. (1977), Persson (*op. cit*.), Santantonio (1979), Keyes & Grier (1981), Deans (1981).

Roots make a considerable contribution to the organic matter of the mineral soil. Thus, a high amount of soil organic matter in Ih 0, which must originate to a great extent form dead roots, was found in the mineral soil horizon, whereas about one-third of the total amount was estimated in the F/H layer (cf. Staaf & Berg, 1980). No significant effect on the accumulation of soil organic matter and carbon in the F/H layer or the mineral soil by the removal of felling-litter (from stratum I) and the distribution of it on the remaining parts of the investigation area (stratum II) was noted (cf. Staaf & Berg, op.cit.). Nor was any appreciable influence on the temporal pattern of changes in the fine-root biomass or necromass between the two strata indicated (see Results).

In the early phase after clear-felling, the deposited coarse litter components on the forest floor (e.g. twigs and branches) and the remaining large diameter roots and the stump in the soil contribute greatly to the accumulated dead plant material. Although, the supply of coarse-root components may be substantial, a long period of time is required to reduce all the material to the black amorphous state of the F/H layer. Note also, the time lag between the time of clear-felling and the point at which the roots have died completely. Wood and bark from large diameter roots (especially heartwood of stumps and coarse lateral roots) may remain essentially undecayed for several decades in the forest soil (cf. McFee & Stone, 1966, Borman & Likens, 1979 p.18-20).

A high lignin level in the litter substrate, furthermore, strongly retards the weight loss of the cellulose and hemicellulose components and slows down the decomposition rate (cf. Fogel & Cromack, 1977; Berg & Staaf, 1980). Large diameter roots, which may be classified as woody roots (cf. Lyford, 1975), contain proportionally more lignin than the non-woody roots, e.g. the fine roots.

The fine roots of Scots pine occupy a very distinct < 1 mm diameter class (average diameter ≈ 0.5 mm); this accounts for approximately 90 % of the total root length (cf. Persson, 1980). The major changes in the weight of the fine-root biomass of Scots pine are concentrated to the < 1 mm diameter class. Changes in other quantitative root variables, such as root length, surface area, volume and the number of root tips (e.g. short-root endings/mycorrhiza) are closely correlated with the changes in weight (cf. Persson, 1980). General valid conclusions on the longevity of the fine-root populations are difficult to find in literature, reported longevity of tree roots ranges from a few days to years (cf. Lyr & Hoffman, 1967; Head, 1973; Herrman, 1977).

Fine-root ramifications may remain for a relatively long period of time with a major portion of the absorptive zones inactivated (dormant/suberized), but still alive (Wilcox, 1954). The starch reserves, which are mainly concentrated to the 2-5 mm fraction, are important for satisfying the demand of the expanding fine root system (Ericsson & Persson, 1980). It is reasonable to conclude that the carbohydrate reserves present in the tree roots before the clear-cutting, were sufficient to maintain the fine-root biomass on a rather stable level for a long period of time. The share of dead fine-root ramifications increased as the root systems died off; however, later they kept to a slowly decreasing level. The decomposition rate in large-diameter root fractions (e.g. woody roots > 1 mm in diameter) is partly determined by the ligning concentration but is also influenced by the nutrient concentrations in the plant material (cf. Berg & Staaf, 1980). Evidently, the < 2 mm fine-root class of Scots pine contains a fairly substantial 1-2 mm fraction, which is more slowly decomposed.

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Table 1. Changes in different diameter classes of *Pinus sylvestris*, *Calluna vulgaris* and *Vaccinium vulgaris* roots (g DW 85°C m^{-2}) before and after clear-felling in Ih 0. The clear-felling took place in March-April 1976. The estimates are given ± one standard error. The number of samples on each sampling occasion was 18, in each of two strata, which, in the clear-cut phase, were designed as areas with (I) and without (II) twice the ordinary amount of felling litter. - denotes absence, 0 denotes a value smaller than 0.5.

	October 7, 1975		June 5, 1976		September 23, 1976		June 27, 1977		September 29, 1977		October 18, 1978		November 11, 1979		October 29, 1980	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
Pinus sylvestris																
Biomass																
< 2 mm	236±23	256±25	167±20	151±15	192±19	126±17	123±20	123±18	97±12	99±12	-	-	-	-	-	-
2-10 mm	280±64	371±186	264±56	274±83	396±129	112±38	666±254	510±184	479±143	337±80	-	-	-	-	-	-
0-10 mm	516±67	626±188	431±57	426±81	587±132	238±40	788±252	633±185	576±144	435±81	-	-	-	-	-	-
Necromass																
< 2 mm	145±22	123±20	71±10	75±8	83±15	128±17	71±8	72±8	82±11	106±7	215±21	217±22	205±30	183±20	134±17	119±14
2-10 mm	129±44	105±33	94±25	55±14	45±28	51±21	66±17	84±22	116±32	79±15	616±106	435±45	398±46	356±57	145±23	133±32
0-10 mm	274±51	228±36	165±26	129±17	128±37	178±26	137±18	156±24	198±32	185±17	831±113	652±154	603±63	539±66	280±29	252±31
Biomass + necromass																
< 2 mm	381±32	379±35	238±26	226±17	275±24	254±22	193±25	195±23	179±20	205±15	215±21	217±22	205±30	183±20	135±17	119±14
2-10 mm	409±88	476±183	359±61	330±88	441±125	162±45	732±253	595±191	595±141	416±77	616±106	435±45	398±46	356±57	145±23	133±32
0-10 mm	790±91	855±196	596±65	556±86	715±131	416±48	925±249	789±192	774±143	620±81	831±113	652±154	603±63	539±66	279±29	252±31
Calluna vulgaris																
Biomass																
< 2 mm	130±18	103±10	117±18	104±14	116±37	116±27	72±12	67±11	88±26	68±7	-	-	-	-	0	0
2-10 mm	122±41	82±26	145±40	138±44	133±46	178±45	72±21	55±27	52±16	93±38	-	-	-	-	-	-
0-10 mm	252±53	184±27	262±50	243±51	249±59	294±51	144±27	121±34	140±35	161±39	-	-	-	-	0	0
Necromass																
< 2 mm	91±16	66±11	48±10	68±16	12±70	62±28	22±7	51±13	26±10	50±14	137±27	137±31	62±17	84±15	80±15	94±17
2-10 mm	45±14	109±31	61±22	118±73	58±23	19±12	100±26	179±39	95±25	136±34	148±58	153±48	136±44	121±44	153±38	144±21
0-10 mm	137±22	175±37	109±24	186±88	69±24	81±28	122±28	230±47	121±27	186±41	284±71	291±49	198±53	204±54	233±47	238±29
Biomass + necromass																
< 2 mm	221±24	168±16	165±22	172±26	128±41	178±44	94±16	118±20	114±35	118±15	137±27	137±31	62±17	84±15	80±15	94±17
2-10 mm	168±42	190±43	206±49	257±84	190±45	196±50	172±37	233±60	148±30	229±47	148±58	153±48	136±44	121±44	153±38	144±21
0-10 mm	389±57	359±49	371±61	429±107	318±57	375±62	266±42	351±76	261±51	347±51	284±71	291±49	198±53	204±54	233±47	238±29
Vaccinium vitis-idaea																
Biomass																
< 2 mm	70±14	120±17	81±17	68±14	123±36	73±26	129±21	84±13	130±30	85±15	-	-	-	-	0	0
Necromass																
< 2 mm	67±20	59±9	65±17	55±11	21±11	21±11	89±17	126±14	118±22	145±13	75±19	64±16	71±13	66±15	108±24	134±12
Biomass + necromass																
< 2 mm	137±33	179±20	145±30	123±17	144±40	94±30	218±30	211±21	248±41	231±14	75±19	64±16	71±13	66±15	109±28	134±12

Table 2. The vertical distribution of different diameter classes of *Pinus sylvestris*, *Calluna vulgaris* and *Vaccinium vitis-idaea* roots(g DN 85°C m^{-2}) in Ih 0 and Ih V. The estimates are given ±one standard error. The sampling in Ih 0 was carried out on June 1-8th, 1976 and in Ih V on September 8-14th 1975. The sampling quadrats (50x50 cm) were randomly distributed, in special randomly selected larger areas for intensive field samplings in the stands. All roots within a frame of 50x50 cm were then excavated, starting with the F/H layer, continuing with 10 cm sections of the mineral soil down to a depth of 60 cm. The number of replicates was 12 in Ih 0 and 7 in Ih V. - denotes absence, 0 denotes a value smaller than 0.5.

	Ih 0:I-II								Ih V							
	Tot.	F/H	0-10	10-20	20-30	30-40	40-50	50-60	Tot.	F/H	0-10	10-20	20-30	30-40	40-50	50-60
Pinus sylvestris																
Biomass																
< 2 mm	221±23	79±12	59±7	37±8	18±4	20±6	6±2	1±1	189±22	99±20	72±10	15±6	2±1	1±1	1±1	1±1
2-10 mm	209±26	25±7	115±22	27±8	16±5	21±6	3±1	1±1	269±33	11±4	197±23	56±27	2±1	1±1	1±1	-
0-10 mm	430±46	105±15	175±28	64±15	33±7	42±12	9±4	2±1	458±44	110±20	269±27	71±33	4±2	2±1	1±1	1±1
> 10 mm	86±20	-	81±20	2±2	-	0	3±3	-	-	-	-	-	-	-	-	-
Necromass																
< 2 mm	59±6	21±3	16±2	10±2	5±1	5±2	2±1	1±1	22±4	4±4	16±4	2±1	1±1	1±1	-	-
2-10 mm	42±5	5±1	23±4	5±2	3±1	4±1	1±1	1±1	122±21	20±8	87±17	14±9	-	1±1	-	-
0-10 mm	101±11	27±4	39±6	15±4	8±2	10±3	2±1	1±1	144±19	24±8	103±16	16±10	1±1	1±1	-	-
> 10 mm	17±4	-	16±4	0	-	0	1±1	-	-	-	-	-	-	-	-	-
Biomass + necromass																
< 2 mm	281±30	101±16	75±9	47±10	22±5	26±8	8±3	2±1	211±19	103±49	87±11	16±6	3±1	1±1	1±1	1±1
2-10 mm	251±32	31±9	138±26	33±10	19±6	26±7	4±2	1±1	391±26	32±22	285±22	71±33	3±1	1±1	1±1	-
0-10 mm	532±57	132±19	214±34	80±19	41±9	51±15	12±5	2±1	601±37	136±19	372±27	87±40	4±2	2±1	1±1	1±1
> 10 mm	104±25	-	97±24	3±2	-	1±1	4±4	-	-	-	-	-	-	-	-	-
Calluna vulgaris																
Biomass																
< 2 mm	51±12	39±10	9±2	2±1	1±1	0	-	-	82±9	61±7	20±2	1±1	0	-	-	-
2-10 mm	66±19	64±19	3±1	0	-	-	-	-	132±15	124±16	8±2	-	-	-	-	-
0-10 mm	117±30	103±28	12±3	2±1	1±1	0	-	-	214±17	185±18	28±3	1±1	0	-	-	-
Necromass																
< 2 mm	37±7	31±6	5±2	1±1	0	0	-	-	36±7	32±7	4±1	-	-	-	-	-
2-10 mm	107±28	104±27	3±2	0	-	-	-	-	91±23	66±18	25±7	0	-	-	-	-
0-10 mm	144±35	135±32	8±3	1±1	0	0	-	-	127±25	98±19	29±8	-	-	-	-	-
Biomass + necromass																
< 2 mm	88±17	70±14	14±3	2±1	1±1	0	-	-	118±12	93±11	24±2	1±1	0	-	-	-
2-10 mm	173±39	168±38	5±3	0	-	-	-	-	223±35	190±32	33±7	0	-	-	-	-
0-10 mm	261±56	238±51	20±5	2±1	1±1	0	-	-	340±40	282±34	57±9	1±1	0	-	-	-
Vaccinium vitis-idaea																
Biomass																
< 2 mm	105±19	97±20	7±2	0	1±1	-	-	-	153±11	97±5	56±11	0	-	-	-	-
Necromass																
< 2 mm	69±17	64±17	5±2	0	0	-	-	-	50±18	29±5	21±4	0	-	-	-	-
Biomass + necromass																
< 2 mm	174±23	161±23	12±3	1±1	1±1	-	-	-	203±25	126±9	76±11	1±1	-	-	-	-

Table 3. Average biomass and length of the fine roots of *Pinus sylvestris* (< 1 mm and < 2 mm in diameter) during the 1974-75 samplings in Ih II (stratum I and II) and in Ih V. The total number of replicates was 208 in Ih II (in each stratum) and 210 in Ih V. The estimates are given ± one standard error. The ratios between the < 1 mm and the < 2 mm root fractions are indicated as a percentage.

	Ih II:I	Ih II:II	Ih V
Biomass (g DW m^{-2})			
< 1 mm	16±1	18±2	74±3
< 2 mm	24±1	28±2	123±4
ratio (%)	66	63	60
Length (mm^{-2})			
< 1 mm	154±12	159±13	1098±50
< 2 mm	169±12	181±14	1194±50
ratio (%)	91	87	92